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Damage to Gratings by Electron Bombardment

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The investigation presented here is a part of a larger, interinstitutional program sponsored by NASA Goddard Space Flight Center which is concerned with the interpretation of spectrographic data in the ultraviolet region of the spectrum as recorded and transmitted from satelite born instrumentation. In particular, one concern is the reliability of ultraviolet spectrographic data obtained during extended periods of orbiting time during which the instrumentation is subject to radiation damage by electrons, protons, gamma radiation, etc.

A second concern is the performance ability and also the cost of master gratings versus replica gratings which would be able to serve the requirements for satelite born instrumentation.

The particular phase of the overall project undertaken in our laboratory was that of possible effects of high energy electron bombardment on spectrographic gratings blazed for the ultraviolet region. Typical, total electron dosages for a one year period range from 10^{12} to 10^{15} electrons per cm^2 at energies up to 1 MeV.

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Therefore, simulated, laboratory experiments were designed to investigate the effects of electron bombardments at these dosages and energies. Master gratings as well as first and second generation gold replicla gratings were studied with the intent of investigating the spectral preformance of the ruled gratings as compared to the replicated gratings when subjected to the electron bombardment.

A series of families of gratings were provided by the Bausch & Lomb Company. Slide 1 These were plane gratings which had a ruled area of approximately (1 cm x 3 cm) on an overall 2 inch square blank. The ruling was 1280 l/mm and the blaze was at approximately 700Å. The gratings are mounted in a machined holder and are masked with a blackened brass plate as shown.

It was decided to restrict our investigating to the wavelength region from the Argone resonance line at 1048Å to the 1302Å oxygen triplet line which would include the region of the L_{α} line at 1216Å.

The experimental configuration used in our laboratory consisted of a McPherson one meter normal incidence vacuum monochromator (Model 225) together with a Hinterreger ultraviolet radiation source lamp and as shown in Slide 2 a 0.3 meter McPherson Czerny-Turner monochromator (Model 218) which served as the test chamber. The two monchromators were jointed together with the aid of a specially designed gate valve assembly as shown in Slide 3. The assembly is attached to the 0.3 meter instrument as shown in Slide 4. The exit slit of the one meter instrument coincided with the entrance slit of the 0.3 meter "test chamber" as shown in Slide 5. The entire configuration was optically alligned with the aid of a low power He-Ne laser and a final check was made by observation of spectral line shapes.

Windowless operation of the monochromators was adopted in order to increase intensities of the spectral line near the M_gF_2 absorption edge, since there was four reflections in the optical path, detection was preformed with the aid of a sodium salicylate coated plate in front of an EMI 9514 photomultiplier tube.

Testing procedures consisted of setting the one meter monochromator on the selected spectral line within the 1048-1302Å range. A M_gF_2 coated reference mirror was inserted in the 0.3 meter instrument in place of the grating and the instrument was set in zero order. Then the intensity of the spectral line was recorded. Next, the gate valve assembly was closed and the 0.3 meter instrument was brought to atmosphere. Then the grating under test was inserted in the 0.3 meter instrument in place of the M_gF_2 mirror. The 0.3 meter instrument was pumped down and the gate valve assembly was reopened. The intensity of the line was recorded in zero order, first order and zero order. The gate valve assembly was closed and the reference M_gF_2 mirror was again inserted and the reflected intensity was recorded as a check. Each of the five spectral lines were repeated in turn. At this point the M_gF_2 mirror was returned for storage in a nitrogen dry box while the gratings were transported in a dessicator to the NASA test facility for the simulated electron exposure. Upon return of these grating to our laboratory the previously outlined test procedure was repeated.

The simulated space damage was carried out with the aid of high energy electron accelerating machines.

The results presented here utilized the facilities of the 3 MeV Dynamitron of the NASA, LRC, SREL laboratory in Newport News, Virginia which were made available for this study. We would like to express our gratitude to Mr. Herb Sowers of SREL and his staff for their suggestions and cooperation during this phase of the investigation, as well as, Mr. Herb Hendricks of LRC during the pliminary stage.

The procedure adopted was to irridiate the gratings in vacuum at approximately 10^{-5}Torr).

In order to eliminate any question of vacuum contamination during electron irradiation by the Dynamitron the following procedure was adopted. A covered companion grating as shown in <u>Slide 6</u> was physically mounted side by side with the subject grating on the target holder. and therefore the two gratings were exposed to the same vaccum environment and also any possible contamination. Slide 7 is a side view of the covered companion (on the left) showing that the covering plate is raised and does not seal the grating from the vacuum environment. The target chamber on which the two gratings were mounted was cooled with water which was a few degrees above abient (room) temperature in order to carry off excess heat as well as preventing any possible effect of cryogentic pumping action of hydrocarbons. Evidence of this type of contamination was found during our preliminary studies and the procedure outlined effectively eliminated this problem.

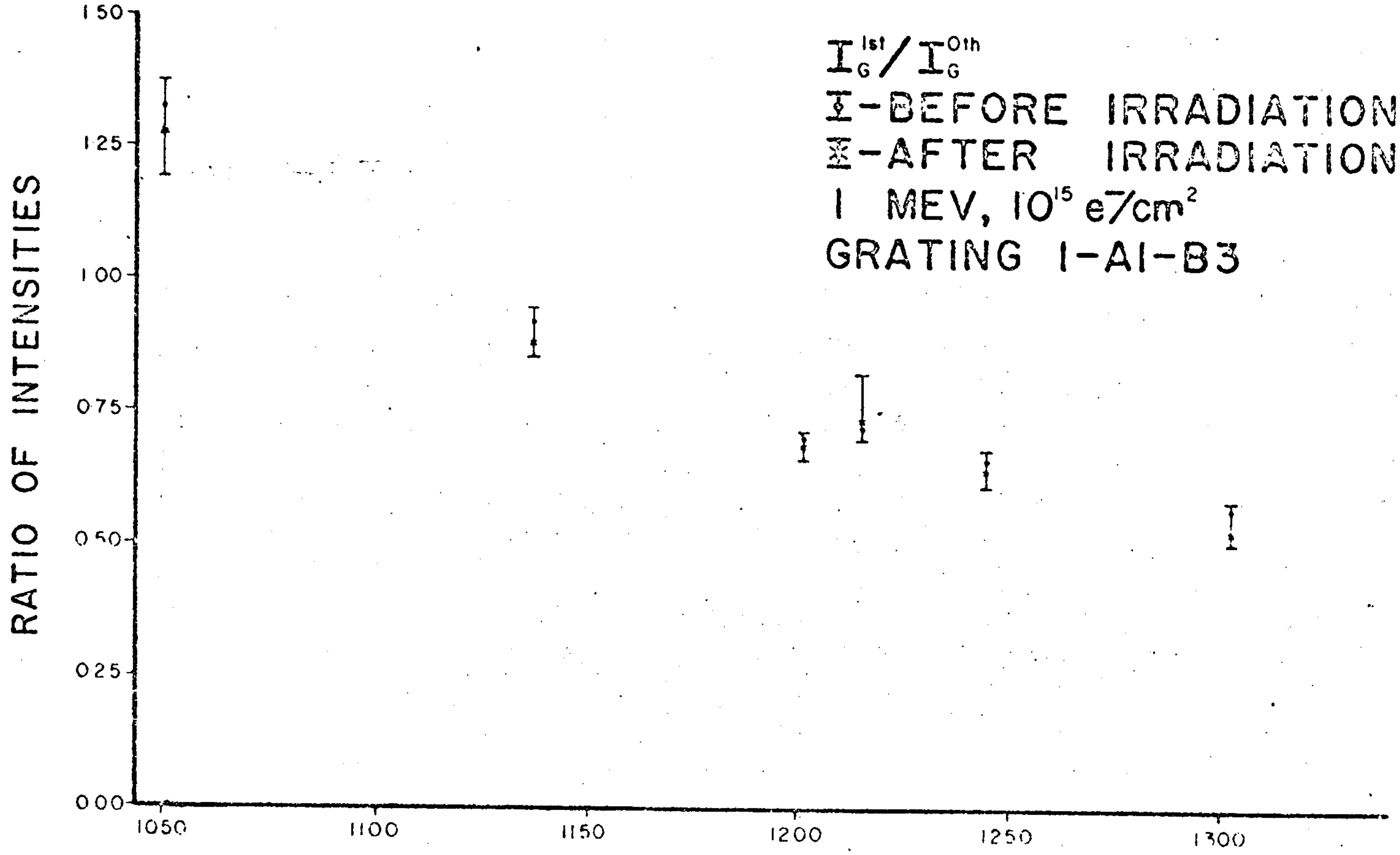
As I understand, Dr. Paul of Goddard Space Flight Center will elaborate on the necessity of such precautions in his paper which follows.

Typical data before and after irradiation is shown in Slide 8 for one of the gold replica gratings for the first order diffraction intensity relative to the zeroth order reflective intensity, together with the corresponding data for the companion grating. Each data point was an average of three runs and the error bars show the fluxation of the actual data points.

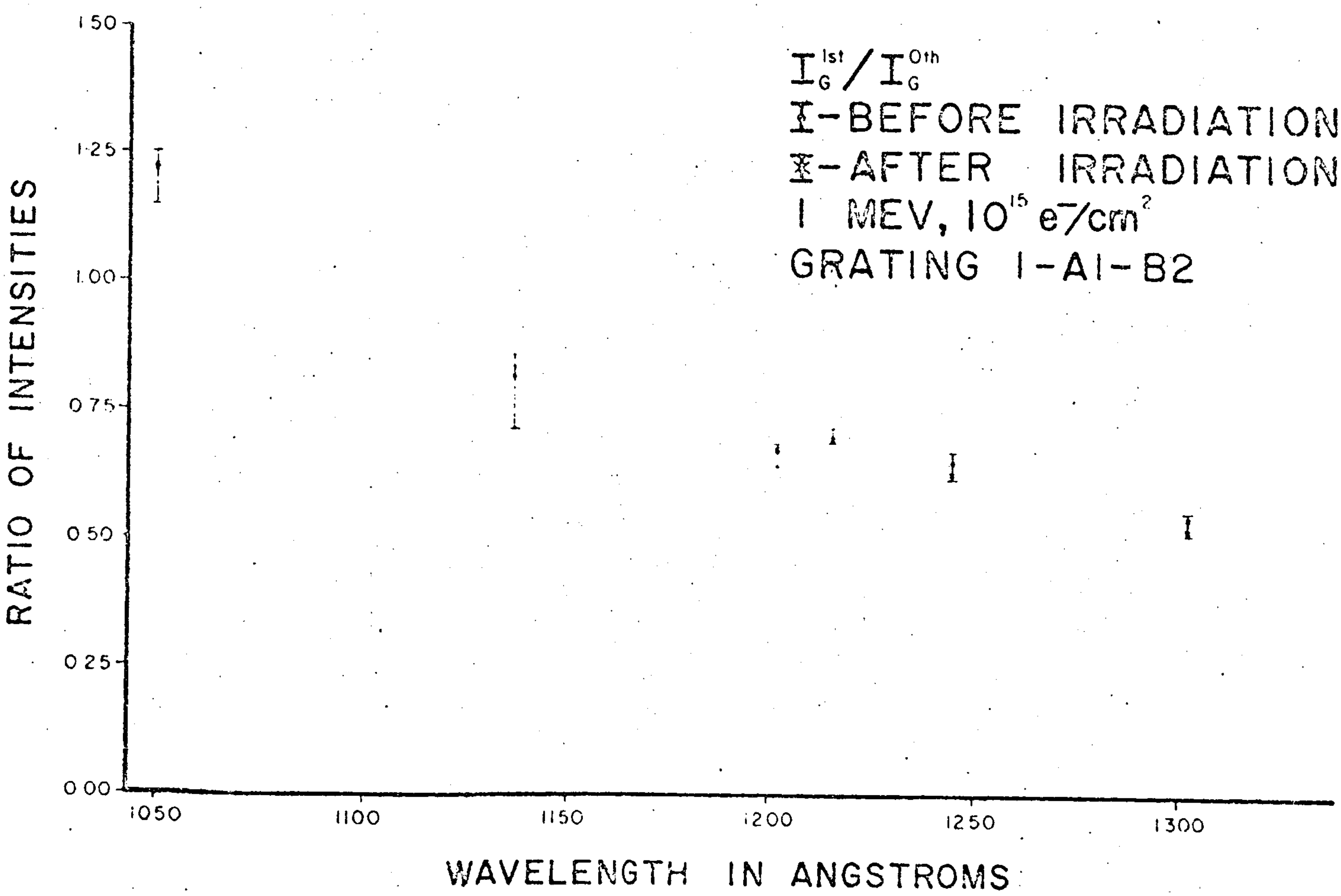
(Slide 9) shows similar data for the first order intensity to the corresponding reflectance intensity of the M_gF_2 reference mirror.

Similar data were obtained for master gratings at 10^{15} electrons per cm^2 at 1 MeV as well as gratings tested at 0.1 and 0.5 MeV.

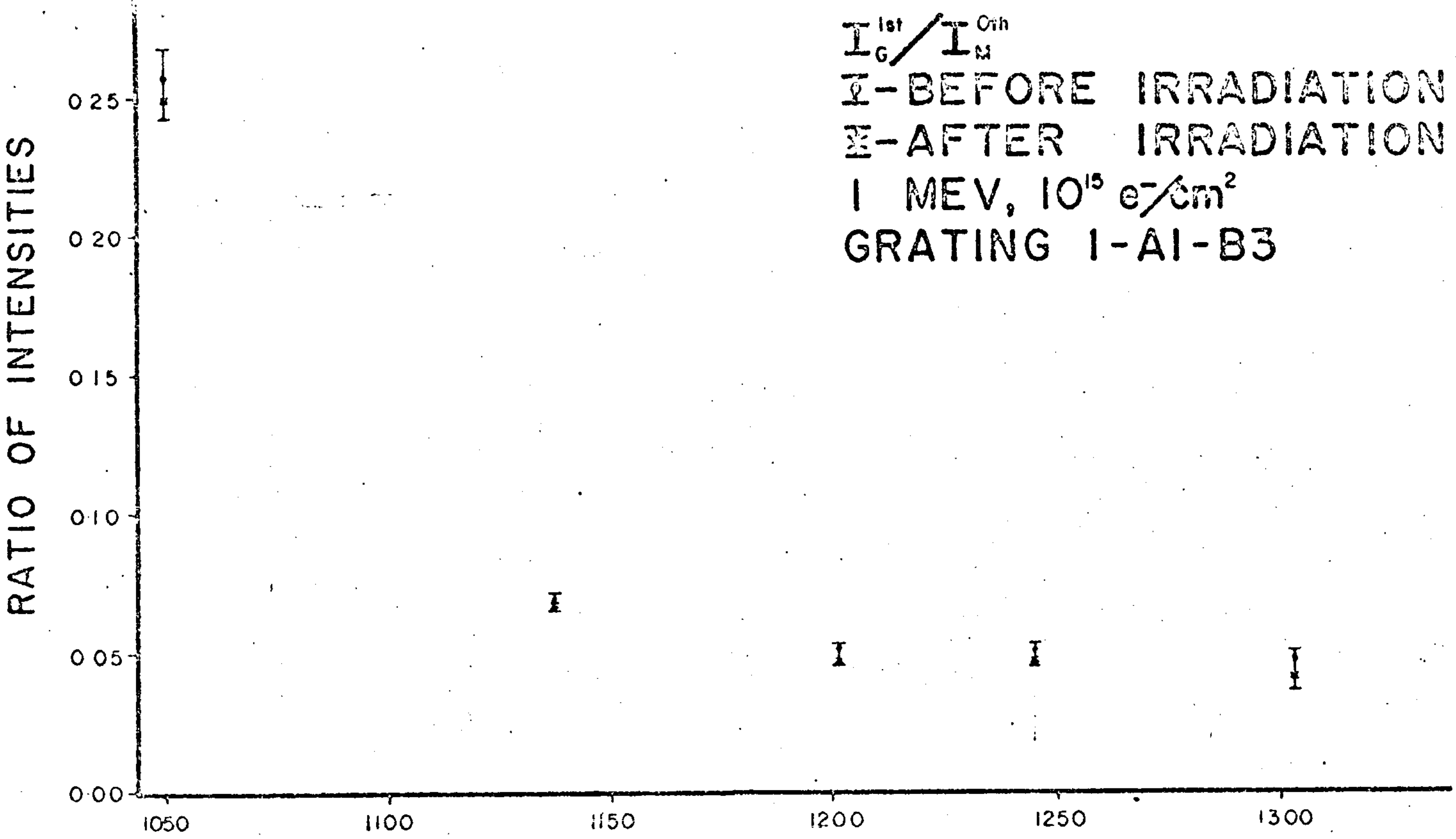
In conclusion, the results presented here indicate that no apparent degredation of preformance at these wavelengths of the ultraviolet gratings, either master or gold replica, occur in a one year simulated electron bombardment damage, although the cosmetic qualities of the gratings appears to suffer to some extent.

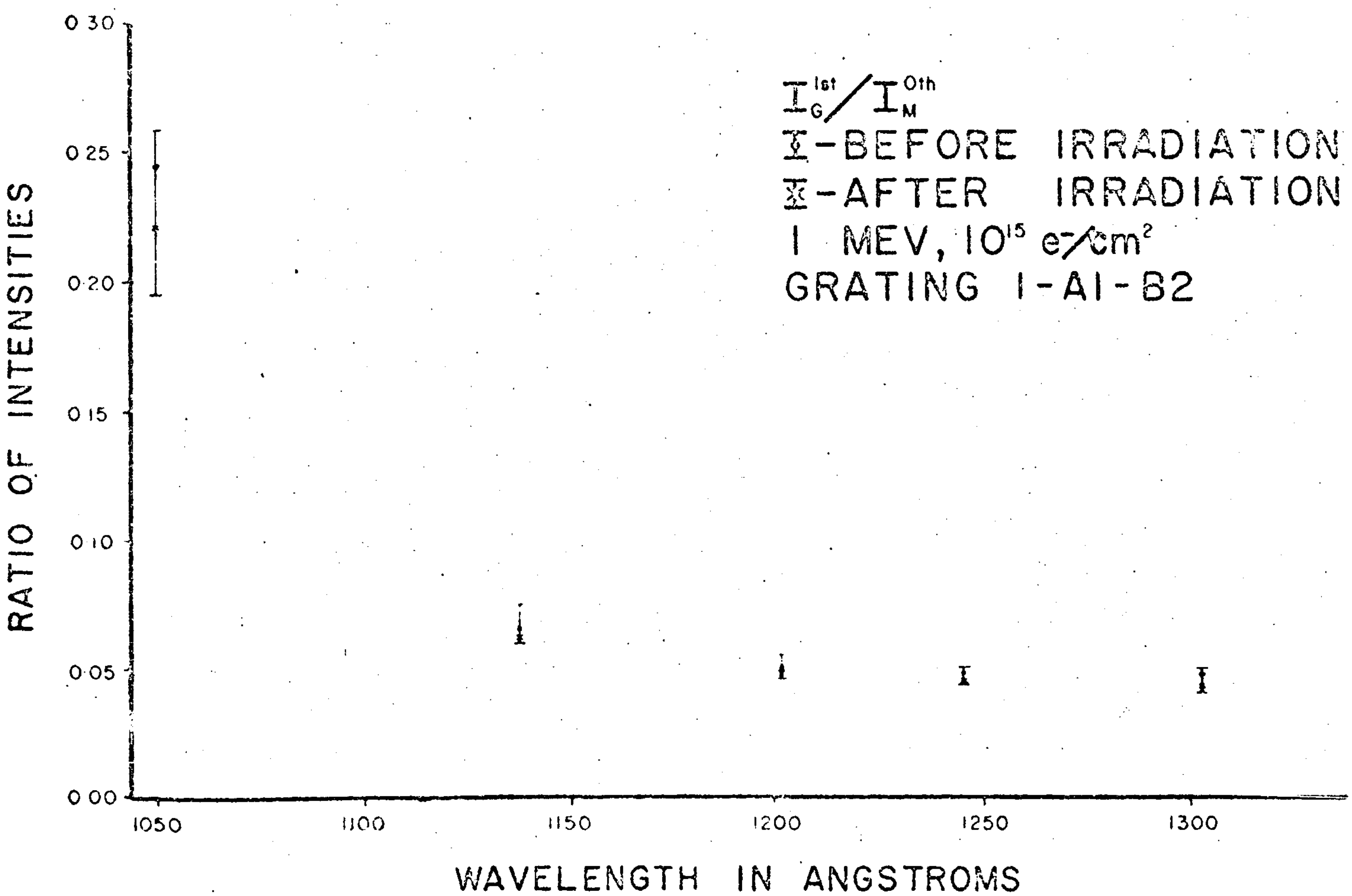


I_G^{1st}/I_G^{0th}
I-BEFORE IRRADIATION
I-AFTER IRRADIATION
1 MEV, 10^{15} e⁻/cm^2
GRATING 1-A1-B3
RATIO OF INTENSITIES
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1050
1100
1150
1200
1250
1300



I_G^{1st}/I_G^{0th}
I-BEFORE IRRADIATION
I-AFTER IRRADIATION
1 MEV, 10^{15} e⁻/cm^2
GRATING 1-A1-B2
RATIO OF INTENSITIES
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1050
1100
1150
1200
1250
1300
WAVELENGTH IN ANGSTROMS


I_G^{1st}/I_M^{0th}
I-BEFORE IRRADIATION
X-AFTER IRRADIATION
1 MEV, 10^{15} e^-/cm^2
GRATING 1-A1-B3
RATIO OF INTENSITIES
0.25
0.20
0.15
0.10
0.05
0.00
1050
1100
1150
1200
1250
1300


I_G^{1st}/I_M^{0th}
I-BEFORE IRRADIATION
X-AFTER IRRADIATION
1 MEV, 10^{15} e^-/cm^2
GRATING 1-A1-B2
RATIO OF INTENSITIES
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1050
1100
1150
1200
1250
1300
WAVELENGTH IN ANGSTROMS

Slide 9